MANGALORE UNIVERSITY

SYNOPSIS

of the Ph.D. thesis entitled

Urban Growth and Impact on the Land Environment: A case study of Barrackpore Subdivision, West Bengal, India

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‘URBAN GROWTH AND IMPACT ON THE LAND ENVIRONMENT: A CASE STUDY OF BARRACKPORE SUBDIVISION, WEST BENGAL, INDIA’

SYNOPSIS

of the Ph.D. thesis to be
Submitted

to

Mangalore University

For the award of the degree of
Doctor of Philosophy
In
Geography

By

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Synopsis of Ph.D. thesis

Title of the Thesis : **'Urban Growth and Impact on the Land Environment: A Case Study of Barrackpore Subdivision, West Bengal, India.'**

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DECLARATION

I hereby declare that the proposed work of research entitled ***'Urban Growth and Impact on the Land Environment: A case study of Barrackpore Subdivision, West Bengal, India' is*** a bonafide record and submitted for the degree of Doctor of Philosophy (Ph.D.) in Geography in Mangalore University. I further declare that this is the result of my research work to the best of my knowledge and it has not been presented or published by other universities or institutions for the award of any degree or diploma.

Mangalagangotri **Sandipta Das**

'Urban Growth and Impact on the Land Environment: A case study of Barrackpore Subdivision, West Bengal, India'

1. INTRODUCTION

Urbanization is a process where the concentration of densely populated settlements is found and their livelihood depends on the non-primary occupations and determines the economic, social, demographic, environmental, technological changes in temporal, spatial, and sectoral manners. Cities or towns have experienced more populous density due to reclassification of the rural-urban structure, migration practices, socio-economic improvement, governmental services, employment opportunities, taking decisions of individuality, industrialization, speculation, land hunger attitude, transportation network raises, and availability of capital market (Bekele, 2005; Bhatta, 2010). Industrialization is the most efficient reason for supporting urbanization. Pull and push methods are effective to attract of rural population towards the urban extent due to high wages than agricultural economic subsistence outcomes (Figure 1).

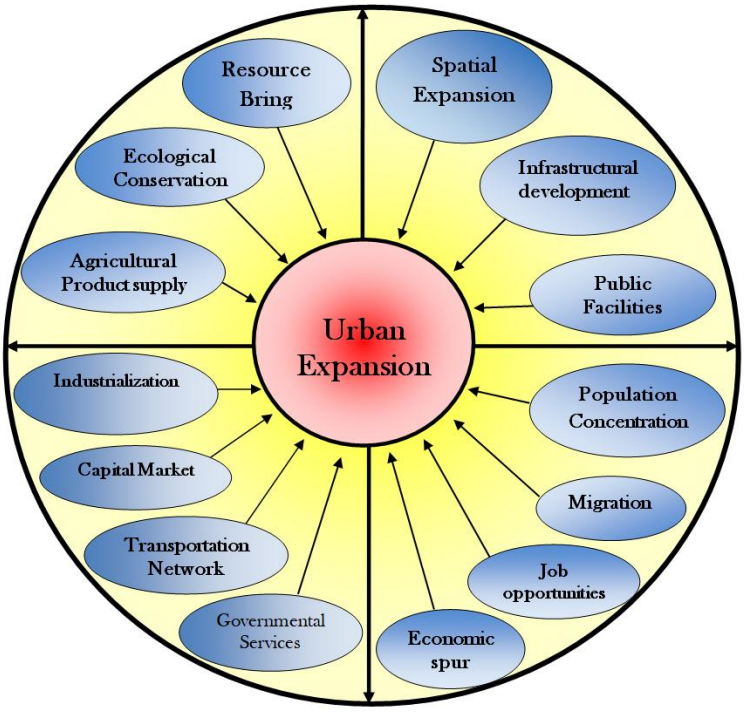


Figure 1. Specific Drivers of Urban Expansion

It has also been a universal discussion regarding population growth as held responsible for environmental problems (Turner et al., 1990). The urban land surface is mostly conquered by impervious surfaces which have impacts to increase the thermal condition of the land. Anthropogenic impacts on the surface water system lead to lost functions of the hydrological and geomorphic processes (Wohl, 2005). Urban is a threat worldwide that obstructed the processes of infiltration, evaporation transpiration, and climatic imbalance (Lindh, 1983; Foster, 1999). Different land-use practices have changes in forms of uncontrolled urbanization through which the productive agricultural lands, forest cover, surface water bodies, and groundwater prospects are being irretrievably lost (Kumar et al. 2007; Pathan and Jothimani, 1989; Kharel, 2010). Expansion of urban land results in runoff rate increases and led to soil erosion (Weng Q, 2001). Urban flooding occurs due to unplanned, uncontrolled, and processes of illegal urbanization (Duran et al., 2012). Carbon emissions are one of the reasons for urbanization (Zhang et al., 2015). Urbanization impacts changes in cities' ecosystem services over the decades (Das and Das, 2019). The development of new urban areas without any necessary measures is always determined negative impacts on the environment such as degradation the condition of reciprocity capacity by increased air pollution level and concentration of pollutant matters (Han et al., 2016; Yang et al., 2018). Population density and concentration of aerosol over an area are highly correlated positively (Wang et al., 2017). Urban land enhances storm intensity, precipitation intensity on a global scale (Fan et al., 2020).

The alteration of land dynamics from rural to urban areas happened due to the factors such as migration, economic development, increase in social infrastructure, increase in the number of facilities and services (Taubenbock et al., 2009; Bhagat and Mohanty, 2009; Altieri et al., 2014)**.** Urban growth is interconnected with higher levels of well-being, higher employment chances, developed infrastructure, services, and a higher standard of living. These types of development and infrastructure activities required vacant land or open field which would be converted into built-up land. This land transformation causes environmental changes surrounding urban areas. It is quite significant to find out the causes of urban settlement growth and its various effects on the land environment in the study area.

The sprawling nature of urban enlargement towards peri-urban, fringe, and village areas is turning down the environmental settings. Urban land use includes the construction of roads,

railways, bridges, residential buildings, industries that would encroach agricultural lands, wetlands, and surface water bodies, mixed vegetation in fringe areas. Due to the influence of urban imperviousness, the urban surface temperature increases in the cities environment, and various pollutant matters dissolve in the surrounding air and water circumstances. The steady growth of the population and its relation to growing built-up could support the gaining impervious surface in this study. As a cost of town construction, the urban landscape ecology has also been affected.

The present study is important in the way of the attempt to comprehend the spatiotemporal expansion of urban character and investigates its impact on the environment by technical analyses. To build the area sustainably, new policies, strategies could be formulated to retain the environment safe for the future in society.

The study region 'Barrackpore' is a subdivision area of the West Bengal state of India that contains 16 municipalities or small towns since 1971. The number of villages is 53 (14 Gram Panchayat) and 24 census towns. The growth rate of census towns was increased by 110% and for villages decreased rate was -47.5% from a 1951-2011census year. So the area is continuously under changes in land dynamics from rural to urban. Industrial influences along the Hooghly river had pulled the population to grow densely among the municipalities from rural places. These urban centers are under the KMDA (Kolkata Metropolitan Development Authority) and part of Kolkata's agglomeration process. As per the literature survey, many research studies have been carried out on the urbanization process and its associated effects on downtown Kolkata city or KMDA. But other parts of the Kolkata agglomeration are not considered as specific studies before literature. No such work has been done before at the Barrackpore subdivision regions as a detailed study where the small towns are getting compacted by settlements due to rapid urbanization. Studying and examine of the micro-scale regions would be useful for the decision-makers and urban planners (Figure 2).

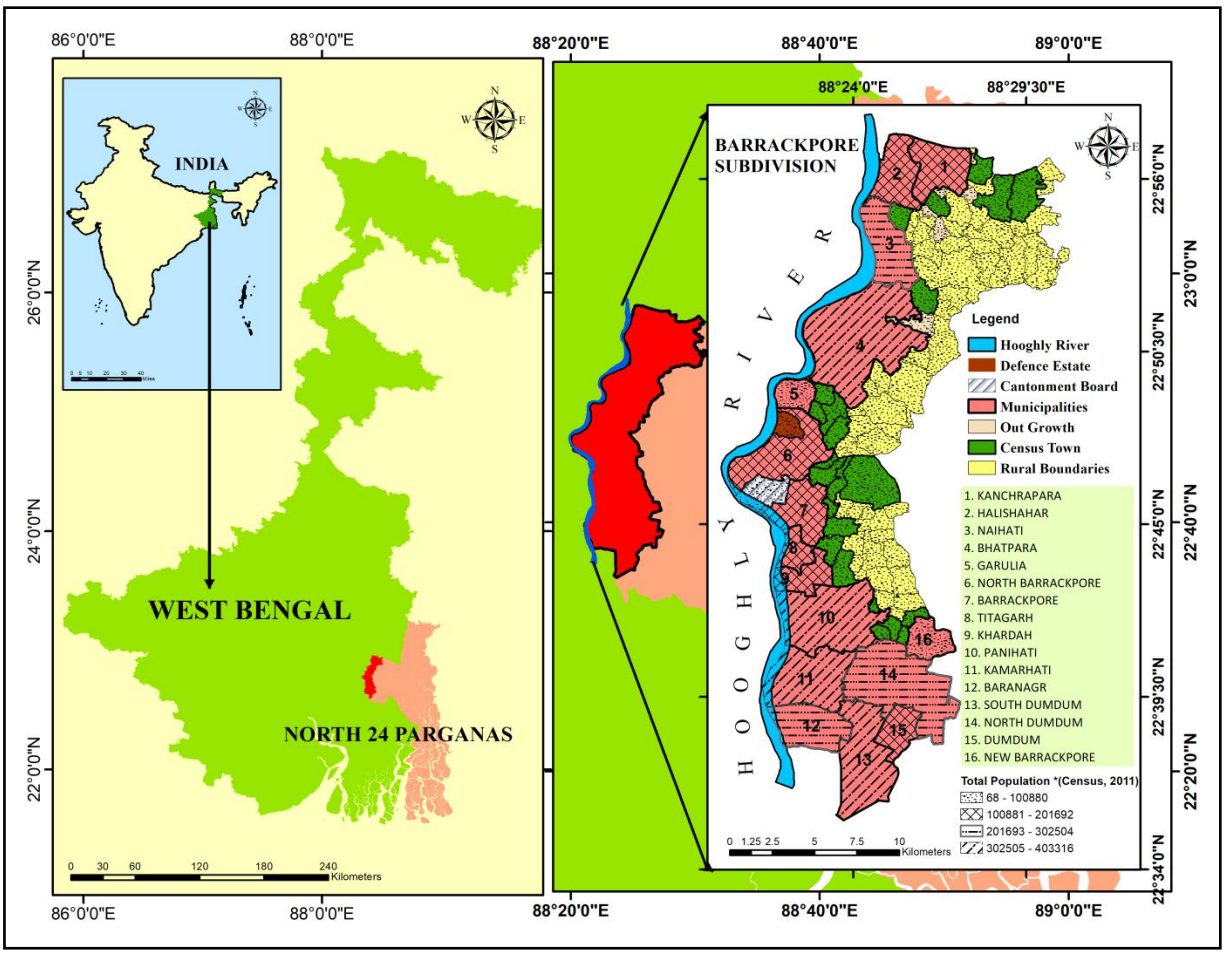


Figure 2. Location of the Study Area

2. OBJECTIVES OF THE STUDY

The specific research objectives and sub-objectives of the thesis are as follows:

1. To discuss the urban functional development with urban facilities and services of each urban unit and the study of the changes of their zonal sphere of influence from 1971-2011.
   - To study the spatiotemporal urban function and facilities distribution in Urban Centre.
   - To assess the population threshold of urban amenities and functional importance changes with their zonal influences of the urban local bodies (ULBs).
2. To analysis the impacts of urban growth on land use/land cover (LULC) transformation.
   - To study the LULC status of six respective decadal periods of 1972, 1980, 1990, 2001, 2010, and 2016 and measure the urban built-up land growth.

- To assess the land use/land cover change (LULCC) through the transformation from non-built-up to built-up land for each respective decade.
- To examine the association between population and built-up growth.

3. To discuss landscape pattern changes in the urban centres as an impact of urban sprawl.
4. To analyze LULC change and its impact on increased land surface temperature (LST).
   - To assess the season-wise variation of land surface temperature changes of the study.
   - To examine the relationship between LST with LULC by the image indices. Normalized Difference Vegetation Index (NDVI) as considered green vegetation status, Normalized Difference Built-up Index (NDBI) as considered built-up land, Normalized Difference Moisture Index (NDMI) considered as wetness status, and Normalized Difference Water Index (NDWI) as surface water surface status.
   - To analysis the hotspot and cold spot thermal conditions and its changes in the study.
5. To study the impact of urbanization on the variations of groundwater quality.
6. To evaluate the impact of urbanization on the air quality condition.

3. OUTLINE OF THE THESIS/ ORGANIZATION OF THE THESIS

The thesis is being organized into three sections and nine chapters. The first section deals with the concept and characterization of urbanization and the selection of study (chapter 1 and 2), where the second section focused on urban development and associate environmental effects (chapter 3–8), and the third section concludes the summary, recommendations, suggestions and future scope of the study (chapter 9). The broad outline of the thesis is outlined below:

CHAPTER 1:

INTRODUCTION OF THE STUDY

The introduction chapter briefly describes the significance of the study, identification of the research problems, research questions, and objectives, review of literature, research approach, research design, the methodological structure, and organization of the thesis (Figure 3).

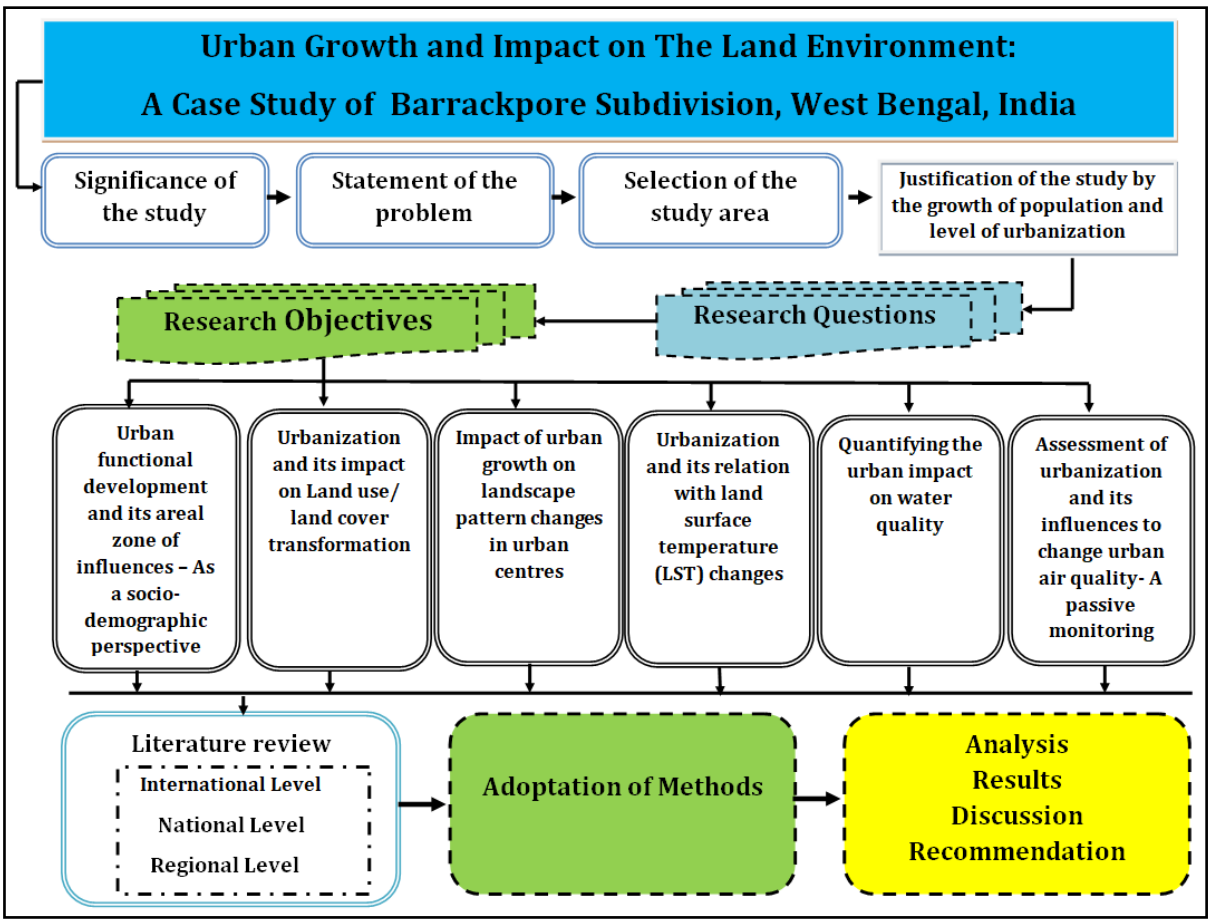

Urban Growth and Impact on The Land Environment:
A Case Study of Barrackpore Subdivision, West Bengal, India
Significance of the study
Statement of the problem
Selection of the study area
Justification of the study by the growth of population and level of urbanization
Research Objectives
Research Questions
Urban functional development and its areal zone of influences – As a socio-demographic perspective
Urbanization and its impact on Land use/ land cover transformation
Impact of urban growth on landscape pattern changes in urban centres
Urbanization and its relation with land surface temperature (LST) changes
Quantifying the urban impact on water quality
Assessment of urbanization and its influences to change urban air quality- A passive monitoring
Literature review
International Level
National Level
Regional Level
Adoptation of Methods
Analysis
Results
Discussion
Recommendation

Figure 3. Conceptual Framework of the Research

METHODOLOGY

The methodological structure of the research was assembled after consideration of previous literature on urbanization and its impact on the surrounding environment worldwide. The methodology has been broadly divided into different divisions, such as data collection, data validation, analysis, final result generation, and identification of potential forthcoming, recommendation, and conclusion. There are detailed procedures through which the process proceeds as particularized further in the Barrackpore Subdivision (Figure 4).

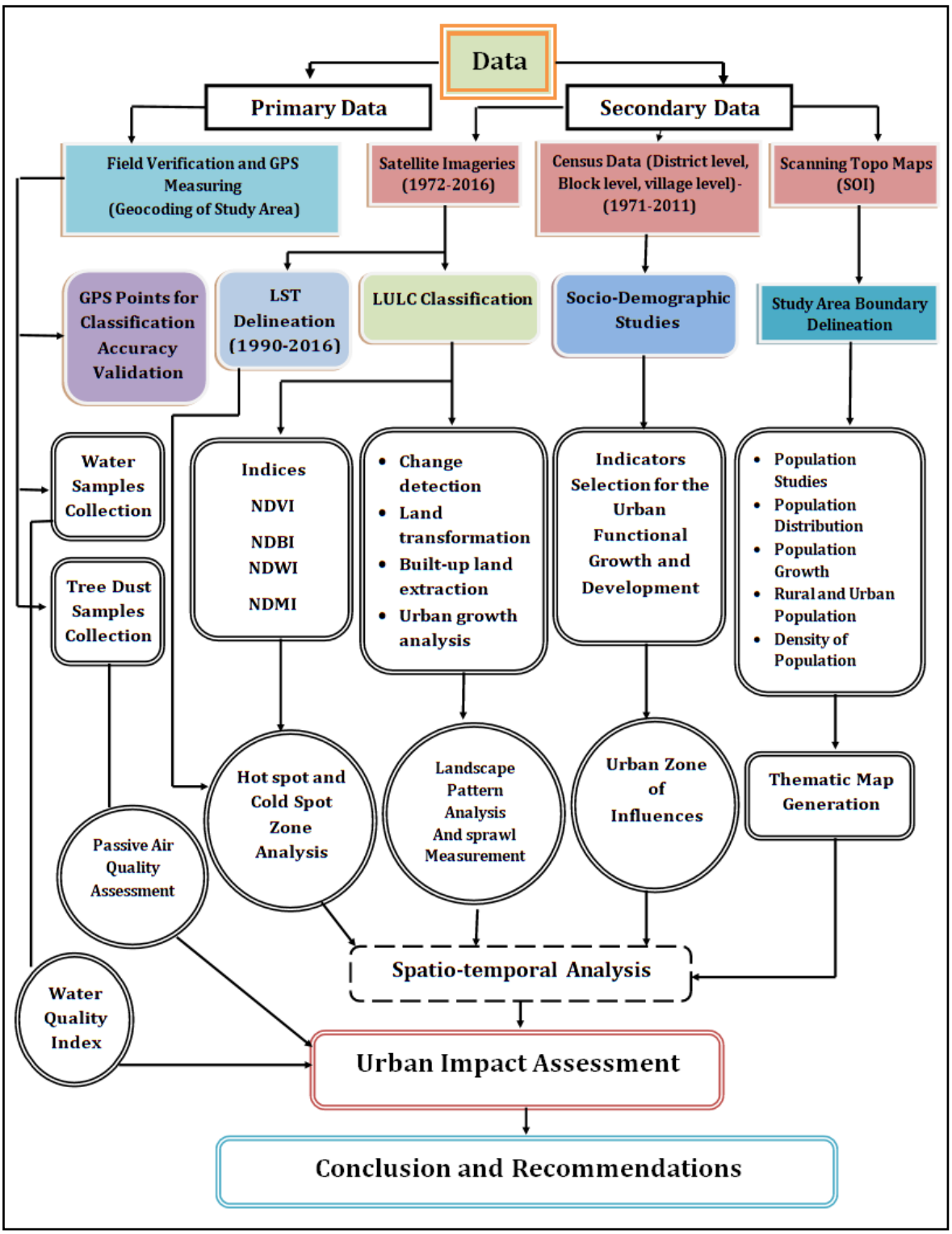


Figure 4 Methodological Structure of the Research

CHAPTER 2:

ENVIRONS OF THE STUDY AREA

The second chapter gives a concise background of the Barrackpore location. The chapter deals with the status of the Barrackpore subdivision like physiographic, climate, soil, socio-demographic structure, and population growth, etc.

Barrackpore Subdivision is one of the subdivisional parts of the North 24 Parganas district of West Bengal as well as part of Kolkata Metropolitan Development Authority (KMDA) for urban infrastructure development. The study area is a conurbation part of KMDA and a combination of urban municipal authorities, census towns, outgrowths, and gram panchayat spread over nearly 3,0,154 ha area located along the right bank of the River Hooghly. The area is situated between 22°36′00″ N and 22°57′00″N and 88°21′00″E and 88°83′00″ E (Survey of India topographical map of F45K5 and F45K6) in the southern part of the Ganga-Brahmaputra Basin. Barrackpore Subdivision area is covered by 2 community development (CD) blocks, 16 municipalities or ULBs (Urban Local Bodies), 24 census towns, 13 police stations, 1 cantonment board, 14-gram panchayats, and 53 villages (Census of India 2011). The boundary from north to south and east to the west extends from Nadia district to Kolkata district and from Hooghly River to Barasat CD block and Amdanga block (Figure 2).

Barrackpore Subdivision has been chosen for the research due to facing more urbanization among the other part of the North 24 Parganas district. The scenario of the total population before 1900 was below 2 lakh and now nearly 41 lakh populations resided here (Figure 5). From 1901 to 1951 was a steady growth of population, but after 1951, it shows the steep angle of growth of population. In 1901, Barrackpore Subdivision was shared 1.2 % of people of the West Bengal state and 20.3% of North 24 Parganas district, but in the recent census of 2011, 4.5% of the state and 41.2% of the district's total population lives here. Development of economic activities along the River Hooghly and industrial location had fetched the peoples from rural and neighboring places and grew the place more population-dense. Barrackpore subdivision is one of the oldest administrative of 24 Parganas district which was densely populated from the earlier period. A higher growth rate has observed during 1951-1961. Since the post-independence period, the population growth rate has been declined. The lowest growth has been recorded during 2001-2011.

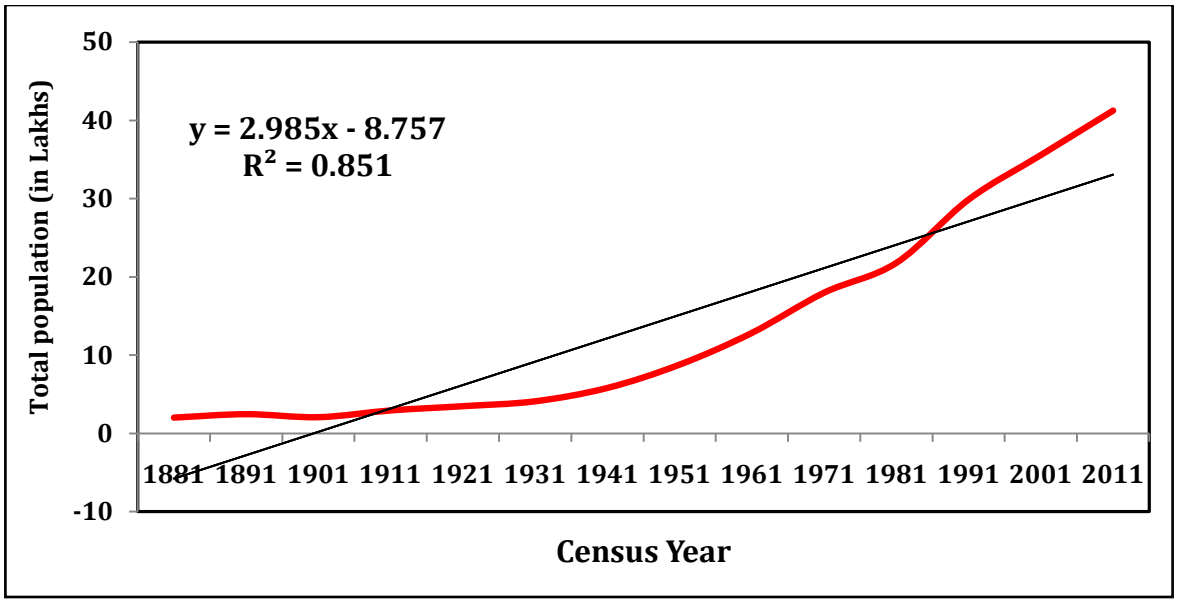


Figure 5. Population trend in Barrackpore Subdivision

CHAPTER 3:

URBAN FUNCTIONAL DEVELOPMENT AND ITS AREAL ZONE OF INFLUENCES- AS A SOCIO-DEMOGRAPHIC PERSPECTIVE

The third chapter provides the urban growth structure from the 1971 to 2011 census years. The functional development and importance of the municipalities with facilities and services are discussed. This chapter enhanced the mean population threshold to get information about the availability of services to the people of the municipalities. Spatiotemporal distributions of facilities are justified by the ratio of advantages and composite functional scores and also focused on the spatiotemporal changes of zonal influence of the municipal towns.

The core sections of the chapter are organized as follows: (I) Arranging the logical research review method systematically to identify the urban sphere of influence zone over two decades, (II) Adopting the appropriate method of spatial and attribute data of whole of the study area including each town, and analyzing them in detail to find out the basic characteristics of changes in urban functional development over the periods (1971-2011 census year), (III) Identifying the socio-economic nodes based rule used in this article to pave the way for understanding the functioning hierarchical order among towns and the overall pattern of the urban sphere of influence of each city, and (IV) Exploring the changing trends and the

transformation of the distributions of each municipal sphere of influence. The logic behind this objective is that small urban centers which suffer from the lack of developing facilities and therefore fail to cover the large surrounding rural areas (Ali and Varshney, 2012). The smaller towns or urban centers need support to grow up to their extreme potentiality so that they can influence their development deeper into a greater distance of the countryside.

Compare to 1971, in 2011 the overall functional weightage is increased since the number of facilities has also increased. Class-I cities have higher functional importance and decline to the next order of the class. In this case, increases in the number of facilities could convert smaller towns into larger-sized cities. It has also been proven that the sphere of influence increases the regional socio-economic conditions of a town. One of the major findings is that the zone of influence area of some towns decreased in 2011 as compared to 1971, as a huge amount of population pressure would impact each small town during 1971-2011. In the meantime, those towns were dependent on their neighboring towns in 1971; but in 2011 had faced all experienced city independence which promotes people to travel within the city for their daily livelihoods. Meanwhile, it is indicated that the increasing number of facilities is not sufficient to fulfill the demand for the present population pressure. The government should implement more services to cover more areas beyond the region of influence (Figure 6).

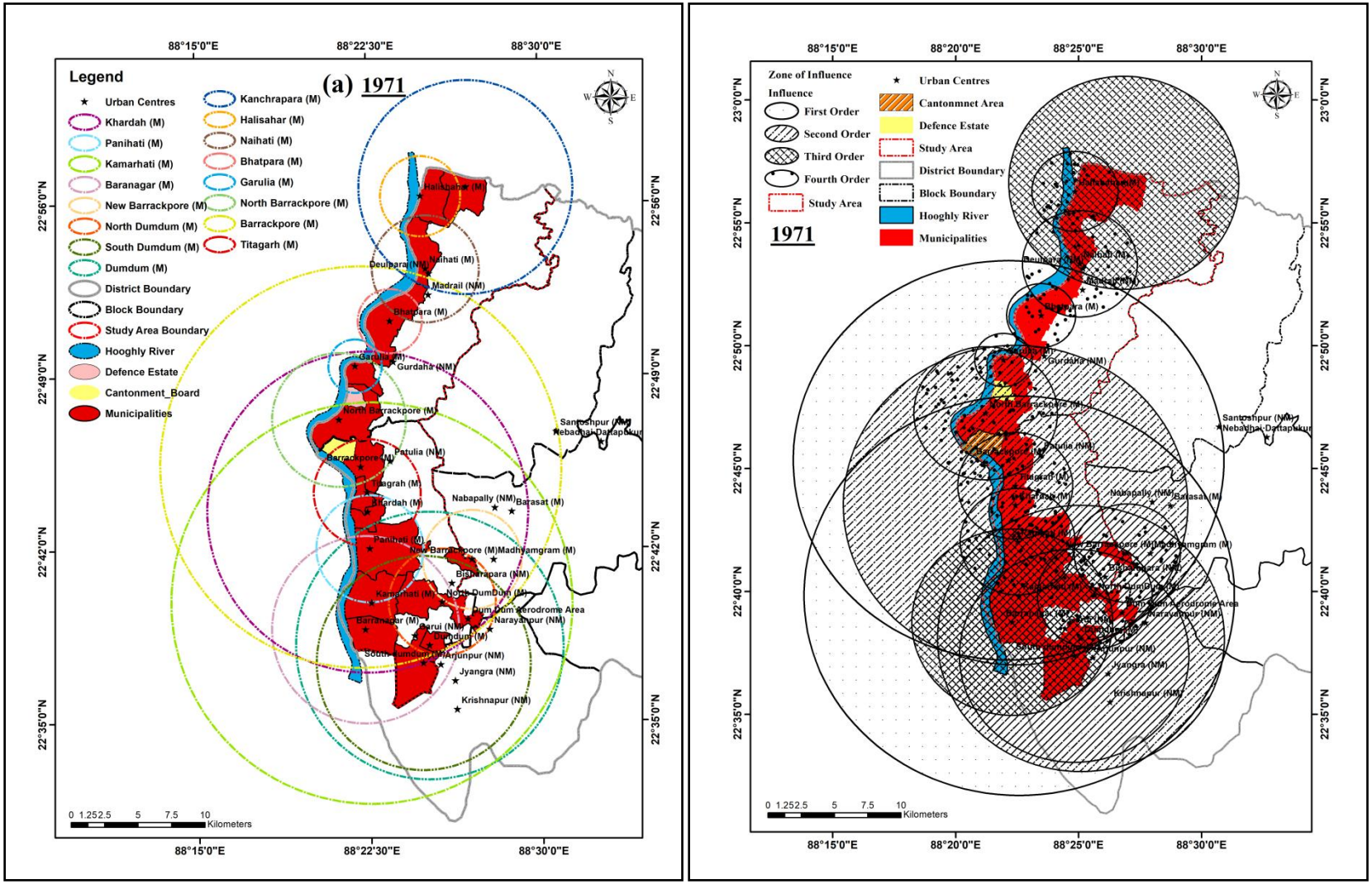


Figure 6. Sphere of Influences (a) 1971 and (b) 2011

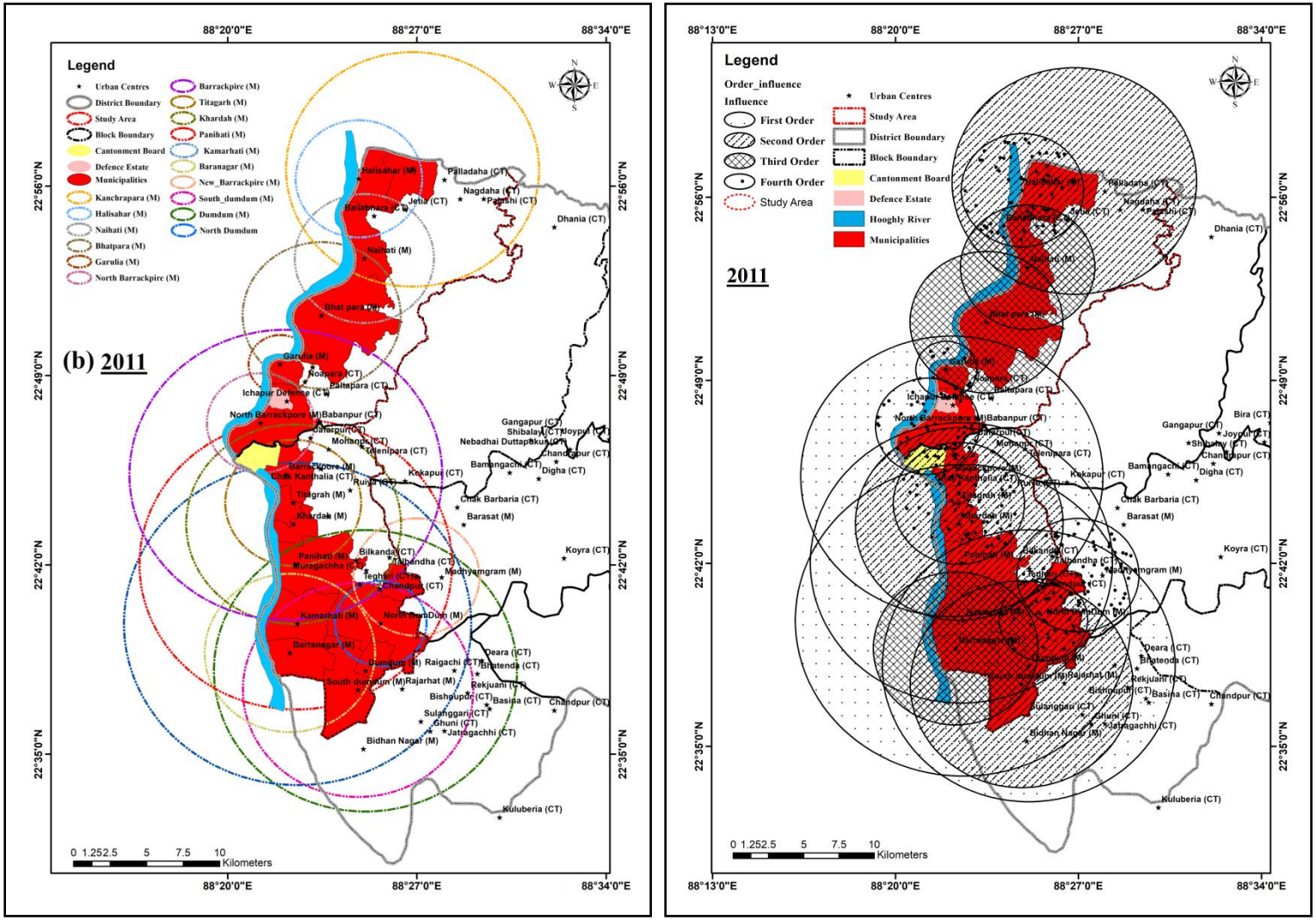


Figure 6. Continued

CHAPTER 4:

URBANIZATION AND ITS IMPACT ON LAND USE/ LAND COVER (LULC) TRANSFORMATION

This chapter provides an assessment of the Land use /Land cover pattern and changes of the last 44 years (1972-2016) through satellite imageries. It also discussed the land use transformation into built-up land and its gain-loss productivity. It focused to describe the driving factors of urban enlargement in municipal towns.

Most of the non-urban areas were changed into built-up land at the cost of vegetation cover and wetland. About 20% (6030.52 ha) of the area under vegetation was transformed into urban land during the1972-2016. Population growth, demand for urban life activities, increasing urban households, and colonies are enhanced to remove trees around the environment. The other important change was observed in agricultural land. Nearly 1804.35 ha (6%) of agricultural land was transformed into urban land. The water surfaces, fallow land, and other land uses were also transformed into impervious areas. The total loss of vegetation was 10031.2 ha (33.2%). The alteration from vegetation to agricultural land was 1867.62 ha (6%). Agricultural land (4848.2 ha) was lost due to changes in land uses. Total conversion from agriculture to other land was 16% during 1972-2016. Vegetation cover, agricultural land, and surface water bodies have been converted into fallow lands by 3.76%, 2.6%, and 1.2%. With high demands for household settlement and the extreme residential threshold limits in municipal areas are forced to expand urban land towards periphery and fringe areas along with transportation nodes. Water bodies and wetland areas have been encroached on by human activities. Nearly 9994.38 ha (33.5%) land out of the total area has remained as no changing area. On the other hand, 20162.12 ha (66.5%) has changed in the different landforms to another landform (Table 1). The built-up area has experienced a 384% growth during the study period. Built-up area has recorded a growth of 6.4% (1972-1980), 8.2% (1980-1990), 11.6% (1990-2001), 10.6% (2001-2010) and 16.2 % (2010-2016) (Figure 7). The development of infrastructure for the rising population has accelerated the transformation of land and degradation of the environment. The expansion of urban land has an impact on the natural environment in terms of microclimate variability, landscape ecology fragmentation, and ecosystem degradation.

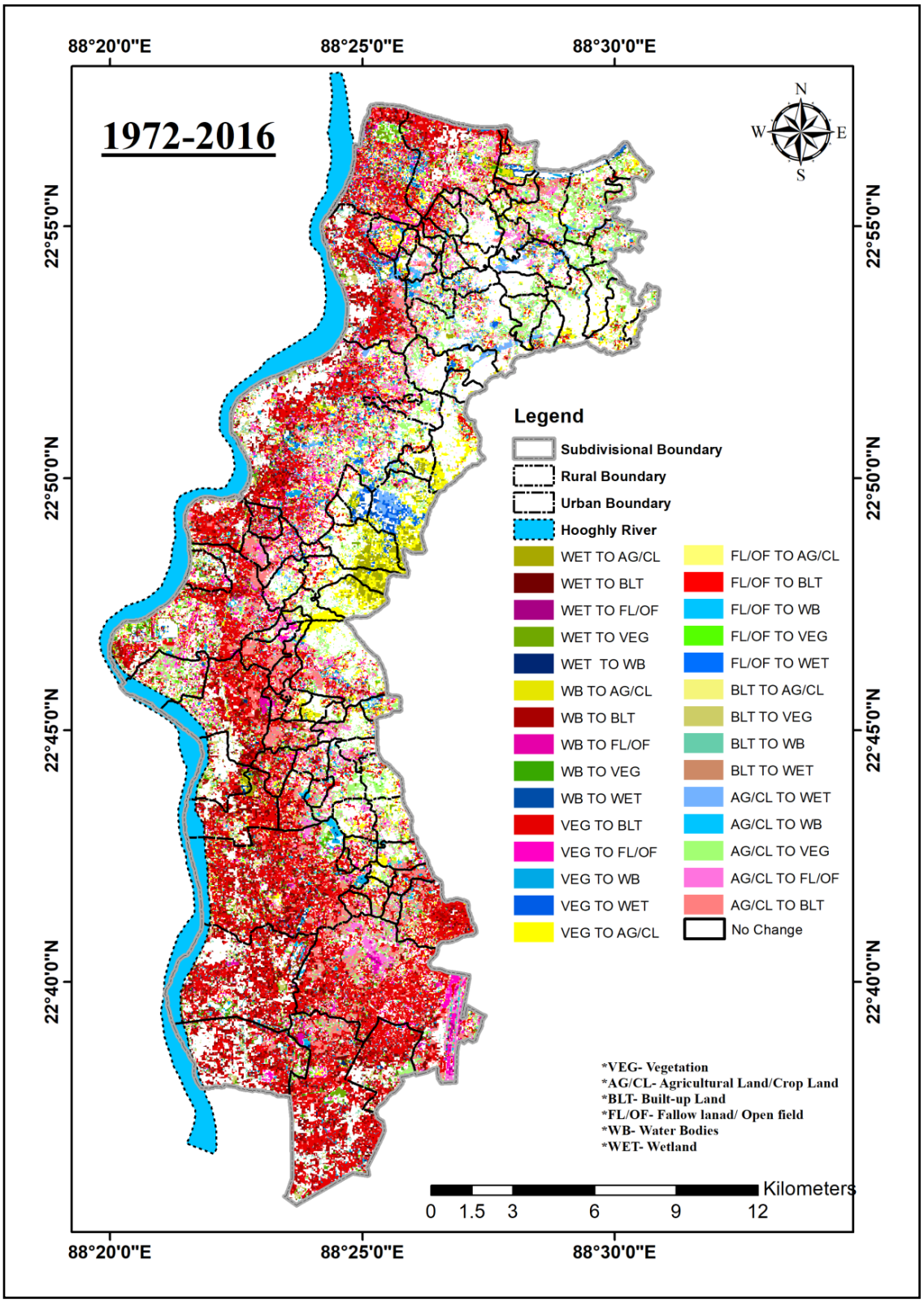


Figure 7 Change Detection Map (1972-2016)

Table 1. Land use/cover Change Matrix from 1972 to 2016 (area in ha)

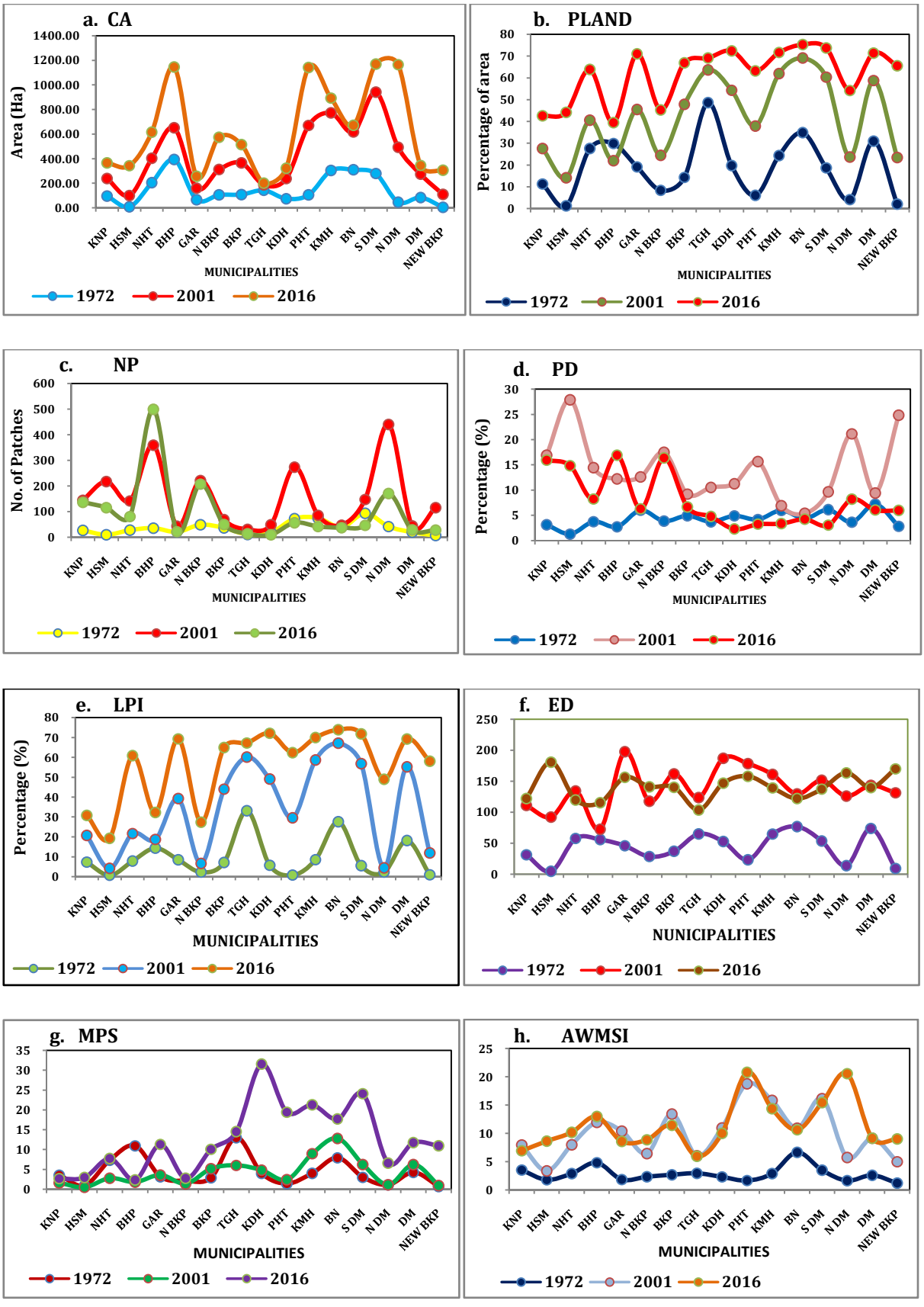
	2016							
	LULC Categories	**Agricultural Land/Crop Land**	**Built-up Land**	**Fallow Land/ Open Field**	**Vegetation**	**Water Bodies**	**Wetland**	**Grand Total**
1972	**Agricultural Land/Crop Land**	3814.14	1804.35	795.23	1742.24	250.13	256.27	8662.35
	Built-up Land	81.50	2040	76.15	202.13	132.29	5.39	2537.46
	Fallow Land/ Open Field	67.17	207.79	57.5	112.73	21.07	6.02	472.28
	Vegetation	1867.62	6030.52	1133.92	3626.83	751.77	247.37	13658.03
	Water Bodies	242.24	1043.60	149.88	334.06	437.75	70.99	2278.52
	Wetland	437.87	1149.78	171.32	494.05	166.70	128.16	2547.86
	Grand Total	6510.52	12276.04	2384	6512.04	1759.71	714.20	30156.5

CHAPTER 5:

IMPACT OF URBAN GROWTH ON LANDSCAPE PATTERN CHANGES IN URBAN CENTRES

The chapter involves the monitoring of land-use pattern changes and its impacts on urban landscape changes of the municipal towns. First analyzed and detected the pattern of land-use changes in temporal order (1972, 2001, and 2016) using remote sensing data in every town. Various landscape metrics (CA, PLAND, NP, PD, LPI, ED, MPS, AWMSI, LSI, CLUMPY, IJI, and AI) were used to capture the dynamism of urban land surface changes and growth considerations. To confirm the sprawl, Shannon's entropy model was computed to understand with detail the local pattern of growth in urban local bodies (UBLs) of the Barrackpore Subdivision.

The result of CA indicates that the built-up area is increasing in all ULBs with time. The PLAND analysis demonstrated a similar trend. The outcome of NP and PD analysis illustrated that the urban landscape fragmentation and sprawling during 1972-2001 but declining the number indicates the compactness of the city during 2001-2016. LPI measurement signifies the rate of fragmentation. From 1972-2001, most of the municipalities had increased the value of LPI excluding BHP, HSM, NEW BKP, N BKP, and N Dm, etc; while LPI was maximum in these ULBs during 2001-2016. ED analysis demonstrated that the sprawling character of the municipalities. MPS and AWMSI indicate the same trend of measurement. Lastly, the four aggregation metrics were applied to analyze municipal aggregation and desegregation in municipalities (Figure 8). All the metrics were performed well. The result of landscape metrics in different ULBs showed that sprawl has happened during the 1972-2001 periods and later these small municipalities had become compact due to more demand for land and population pressures. The small urban class patches at the peripheral zone combined with a single larger patch concerning time. The result of entropy illustrated the direction and zone-wise sprawl of urban land. Mostly eastward direction of towns has a probability to increase in the future while the western side is congested and compact. The index value has provided visualization and quantifying the expanding urban footprint in the study area.


a. CA
Area (Ha)
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
KNP HSM NHT BHP GAR N BKP BKP TGH KDH PHT KMH BN S DM N DM DM NEW BKP
MUNICIPALITIES
1972 2001 2016
b. PLAND
Percentage of area
80 70 60 50 40 30 20 10 0
KNP HSM NHT BHP GAR N BKP BKP TGH KDH PHT KMH BN S DM N DM DM NEW BKP
MUNICIPALITIES
1972 2001 2016
c. NP
No. of Patches
600 500 400 300 200 100 0
KNP HSM NHT BHP GAR N BKP BKP TGH KDH PHT KMH BN S DM N DM DM NEW BKP
MUNICIPALITIES
1972 2001 2016
d. PD
Percentage (%)
30 25 20 15 10 5 0
KNP HSM NHT BHP GAR N BKP BKP TGH KDH PHT KMH BN S DM N DM DM NEW BKP
MUNICIPALITIES
1972 2001 2016
e. LPI
Percentage (%)
80 70 60 50 40 30 20 10 0
KNP HSM NHT BHP GAR N BKP BKP TGH KDH PHT KMH BN S DM N DM DM NEW BKP
MUNICIPALITIES
1972 2001 2016
f. ED
250 200 150 100 50 0
KNP HSM NHT BHP GAR N BKP BKP TGH KDH PHT KMH BN S DM N DM DM NEW BKP
NUNICIPALITIES
1972 2001 2016
g. MPS
35 30 25 20 15 10 5 0
KNP HSM NHT BHP GAR N BKP BKP TGH KDH PHT KMH BN S DM N DM DM NEW BKP
MUNICIPALITIES
1972 2001 2016
h. AWMSI
25 20 15 10 5 0
KNP HSM NHT BHP GAR N BKP BKP TGH KDH PHT KMH BN S DM N DM DM NEW BKP
MUNICIPALITIES
1972 2001 2016

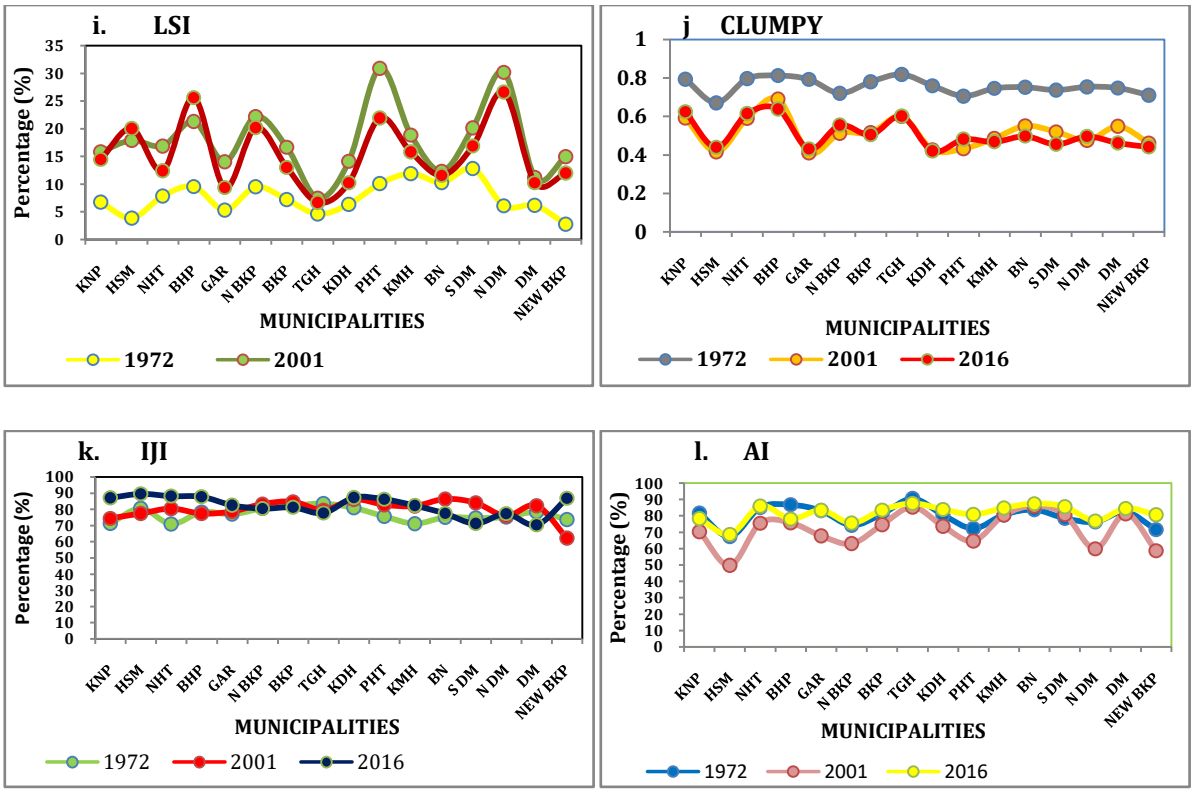


Figure 8. Class Level Landscape Metrics for Municipalities: (a) CA, (b) PLAND, (c) NP, (d) PD, (e) LPI, (f) ED, (g) MPS, (h) AWMSI, (i) LSI, (j) CLUMPY, (k) IJI, (l) AI.

CHAPTER 6:

URBANIZATION AND ITS RELATION WITH LAND SURFACE TEMPERATURE (LST) CHANGES

The chapter discussed the LST variation that was carried out from pixel to pixel by following land transformation, and the transformation of land-induced LST variation at different seasons in a year. A few scholars have touched upon three respective seasonal months (Winter, Summer, and Autumn) to measure LST variations and its relation with different land uses. This chapter aims to detect changes in LST with land use/land cover changes over the decades 1990-2016 of summer, autumn, and winter period (Table 2). This study has also examined temperature characteristics and relationships with different land-use classes through image-based indices such as NDVI, NDBI, NDMI, and NDWI. Lastly, the hot spot and cold spot zone have been investigated among all spatial units in the study area using the autocorrelation approach-based cluster analysis.

Table 2. Seasonal LST Coefficient Variation for Different Periods

Month	Year	Min Temp. (^{0}C)	Max Temp. (^{0}C)	Mean Temp. (^{0}C)	Standard Deviation (SD)	Coefficient of variance (CV)
January	1990	16.56	23.67	18.88	0.82	4.3
	2016	16.91	33.50	21.83	1.28	5.8
April	1990	22.37	34.85	28.40	1.19	4.1
	2016	26.93	41.64	32.21	1.63	5.0
October	1990	19.30	28.37	22.57	1.00	4.4
	2016	21.75	37.76	26.58	1.42	5.3

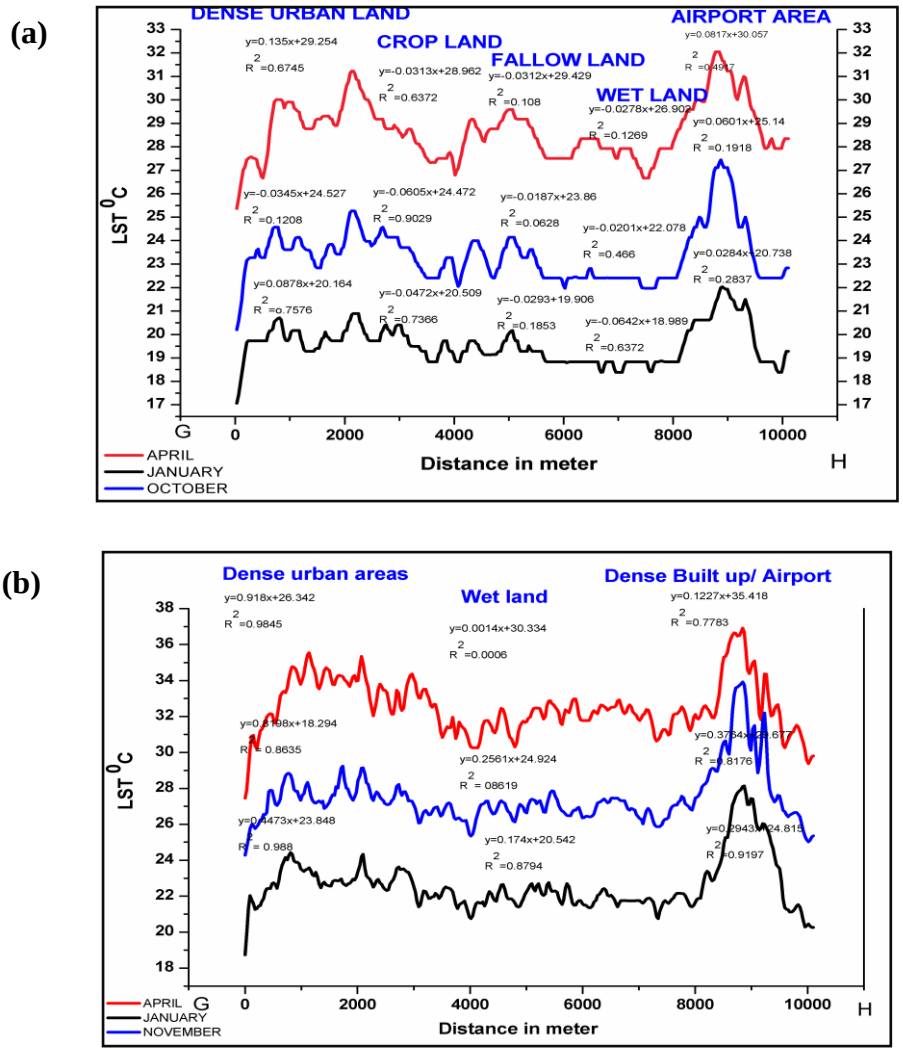


Figure 9. Season-wise LST Variation with LULC Changes (a) 1990 (b) 2016.

The mean LST has changed from non-built-up land (evaporating surface) to built-up (non-evaporating surface) due to changes in surface materials (stone, metal, concrete, etc). Newly urban land transformed from vegetation, agricultural, wetland, fallow land, and water bodies have raised in LST with 3.14°C, 3.11°C, 3.15°C, 3.2°C and 3.19°C in winter seasons; 4.35°C, 4.22°C, 4.28°C, 4.38°C and 4.4° C in summer seasons; and lastly in post monsoonal seasons it has been 4.5°C, 4.36°C, 4.49°C, 4.39°C, and 4.57°C elevated during study periods. Moreover, it is observable that in summer and post-monsoon seasons the average LST rises more than 4°C by conversion of land (Figure 9).

Table 3. Table 6.7 Changes in Hot Spot and Cold Spot Zones during 1990-2016

CATEGORIES	JANUARY		APRIL		OCTOBER/ NOVEMBER	
	Area(ha)	%	Area(ha)	%	Area(ha)	%
Hot Spot to Not Significant	299.74	0.98	2574.08	8.29	0.00	0.00
Hot Spot to Cold Spot	755.63	2.46	0	0	0.00	0.00
Not Significant to Hot Spot	6132.74	19.99	3311.97	10.67	6786.50	20.91
Not Significant to Cold Spot	5756.35	18.76	4820.32	15.53	2462.63	7.59
Cold Spot to Not Significant	3862.99	12.59	4968.06	16.01	1971.20	6.07
Cold Spot to Hot Spot	0	0	1191.27	3.84	0.00	0.00
Persistence Cold Spot	888.48	2.90	0.00	0.00	1527.74	4.71
Persistence Hot Spot	4749.71	15.48	611.53	1.97	6169.13	19.01
Persistence Not Significance	8230.43	26.83	13559.10	43.69	13538.56	41.71

Spatial hot and cold spots cluster zones of LST have been represented season-wise from 1990 to 2016 using the Getis-Ord Gi* statistics. Generally, the hot spot areas are accumulated over the urban areas. According to statistics, the total hot spot areas were increased from 19.9% to 35.3% in January month, 10.25% to 16.40% in April month and 15.38% to 37.4% in November month during the periods. The total cold spot areas were decreased from 19.81% to

15.45% in only April month. The changing scenario of the hot spot zones during January has been transformed from another category was 20%. Only 15.4 % of land areas were persistence areas as hot spot zones. In the northern part, the very hot spot zone has been replaced by a cold spot with 2.4% and the rest of 26. 8% of other land was as not significant land. As similarly in the summer season's total of 14 % of the land was converted as hotspot zones from not significant and cold spot zones (Table 3).

CHAPTER 7:

QUANTIFYING THE URBAN IMPACT ON GROUNDWATER QUALITY

The chapter deals with the physicochemical characteristics of groundwater parameters and describes the suitability of groundwater quality. It focuses on the Water Quality Index (WQI) calculation for the water assessment in urban and rural areas. GIS application has been adopted for mapping the higher and lower zonation of WQI in the overall study. Groundwater quality of Barrackpore residential cum industrial areas was appraised for domestic uses as indicated by BIS (2012) (Table 4). Significant variations have been found in the physicochemical characteristics of 21 groundwater samples over the area. This variation is happened by both natural and anthropogenic factors. The groundwater is classified as neutral to moderately alkaline based on the pH range. Total dissolved solids and EC illustrate a high positive correlation with total hardness, Ca^{2+}, Mg^{2+}, and Cl^{-}. Excluding Mg^{2+} parameters, all water parameters are within the desirable to permissible limits within the study area. Water samples from dense urban areas are more polluted and unfit for consumption, i.e., Naihati, Baranagar, Kamarhati, Barrackpore towns are more polluted. The WQI provides a base scenario 77.36% spatial zones are suitable for drinking uses, 20.60% of land are unsuitable and only 2.03% of land illustrated as excellent. Kanchrapara, Naihati, Barrackpore, Khardah, Kamarhati, Baranagar, North Dumdum, and New Barrackpore towns are having poor water quality and are not considered for water uses, where the rural water samples are all in good condition and that would be considered or recommended for drinking purposes (Table 5). The reasons for the depletion of groundwater quality are mostly natural and anthropogenic sources like human activities, solid waste disposal, and sewage location, etc. A side by the local government may be adopted to manage the groundwater pollution and measures the action before water uses to protect from health effects (Figure 10).

Table 4. Assessment of Water Quality Parameters with Bureau of Indian Standards (BIS, 2012)

Parameters	BIS Standard	% of Sample of Maximum Desirable Limit	Area of Maximum Desirable	% of Sample of Maximum Permissible Limit	Area of Maximum Permissible	% of Sample of Beyond Permissible Limit	Area of Beyond Permissible	Total Area (ha)
pH	6.5-8.5	100	30762.06	-	-	-	-	30762.06
EC	-	-	-	-	-	-	-	-
TDS	500-2000	47.62	17756.36	52.38	13005.70	-	-	30762.06
TH	200-600	4.76	190.27	95.24	30576.37	-	-	30766.64
Alk	200-600	4.76	194.65	95.24	30571.99	-	-	30766.64
Ca^{2+}	75-200	33.33	5153.76	66.67	25611.33	-	-	30765.09
Cl^{-}	250-1000	95.24	30246.00	4.76	521.02	-	-	30767.02
Mg^{2+}	30-100	4.76	36.89	85.71	30670.39	9.52	58.79	30766.08

Table 5. WQI for Urban and Rural Areas

Class categories	Urban Area	Rural Area	% of Urban area	% of Rural area
Excellent	21.86	-	0.07	-
Very Good	601.77	-	1.96	-
Good	15963.90	7706.18	52.02	25.11
Poor	4898.38	383.81	15.96	1.25
Very Poor	895.37	-	2.92	-
Unfit	129.45	-	0.42	-

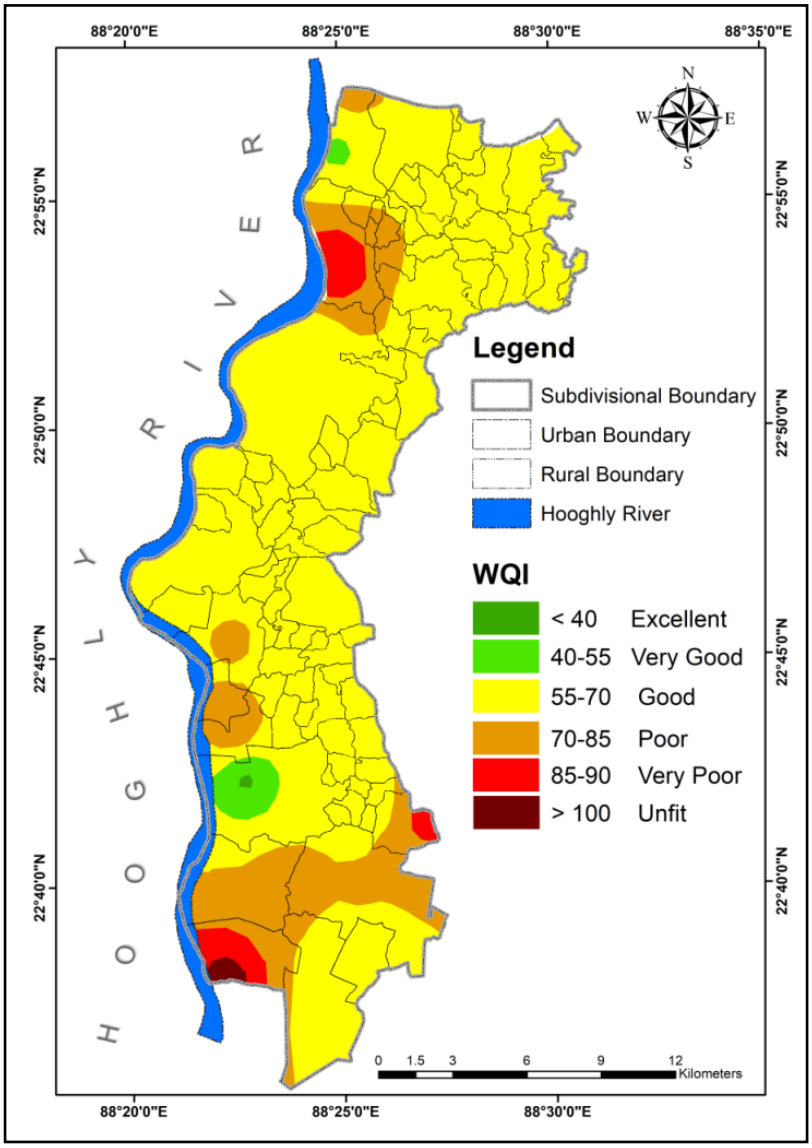


Figure 10. Water Quality Index

CHAPTER 8:

ASSESSMENT OF URBANIZATION AND ITS INFLUENCES TO CHANGE URBAN AIR QUALITY- A PASSIVE MONITORING

Here, the chapter is mainly focused on the characterization of dust deposited on tree leaves and the elemental concentration of airborne particulates in dust along the specific urban gradients. A scanning electron microscope (SEM) and an Energy-dispersive X-ray spectrometer (EDS) were used to analyze the morphological characteristics and composition of the dust (Figure 11). This type of analysis has been considered for air pollution assessment of the study area because this is regarding the environmental concern, less cost-effective. As the study is considered as micro-scale, therefore, air pollution measure stations are very less and not adequate governmental temporal data are available for the necessary information. Attempting the tree leaves dust characterization by the sampling measures would provide the presence of air pollutants (PM_{10} and PM2.5) in the surrounding environment.

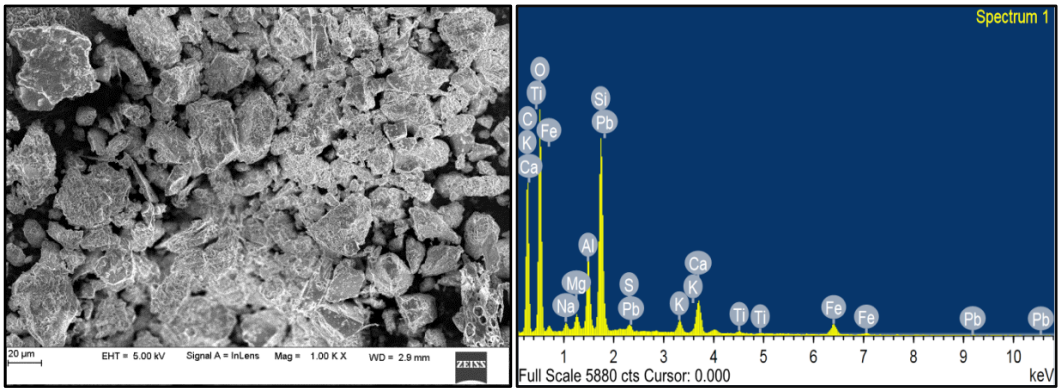


Figure 11. Scanning Electron Microscope (SEM) and Energy-Dispersive X-ray Spectrometer (EDS).

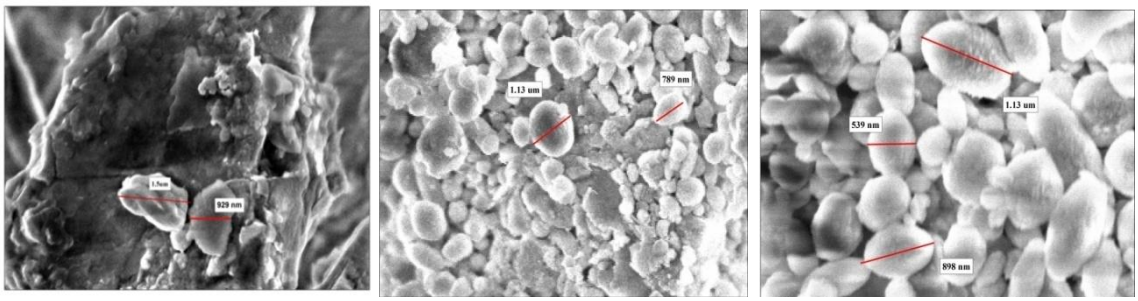


Figure 12. Scanning Electron Microscope of Particles with Size Ranges Observed at Different Sites.

It is observed that the range of size of dust particles on plant leaves varied from less than 1µm to up to 40 µm. The analysis has shown that the majority of the dust particles ranged within a size of < 2 µm which indicates the urban health quality is very poor. The observed particulate can be divided into three groups i.e., (i) ultra-fine particle (<2.5 µm) (ii) finer particle (2.5 µm -10 µm) and (iii) coarse particle (10 µm -40 µm). The EDX spectra result have revealed the presence of elements such as sodium (Na), Magnesium (Mg), Aluminum (Al), Silicon (Si), Sulfur (S), Potassium (K), Calcium (Ca), Titanium (Ti), Iron (Fe), Zinc (Zn), Lead (Pb), Carbon (C), etc. Si-rich is mainly the large particles that indicate the geological origin and the observation of a high peak of carbon (C) rich at all sites due to mainly the biological structural composition of leaf tissues (Figure 12). Smaller particles are mainly associated with various trace elements indicating an origin from vehicular emission. Ca-rich elements were present in samples at each site that originated from construction materials like cement. The wear and tear of tire particles are the common sources of trapped Zn elements in the dust. The presence of Pb in the dust has specified the contribution of deposition from the vehicular exhaust. The considerable source of Fe and Al elements are geological as well as automotive industries as being components of steel and alloys at the sampling sites. X-ray diffraction data have been detected that quartz is dominated in the dust on canopies at each sample station. The different minerals i.e., potassium, magnetite (oxide of iron), Scrutinyite (lead oxide), Cristobalite (a polymorph of silica), silicon oxide (Sio_2), Carbon, feldspar, Calcium oxide, rock-forming minerals potassium and aluminum, titanium are present in the dust.

CHAPTER 9:

SUMMARY, RECOMMENDATIONS AND FUTURE SCOPE OF THE STUDY

The concluding chapter provides the sum-up of all chapters together and presents the findings or summary of the output and lastly, suggestions or recommendation comes into view to improve the environment of the study area. The future scope of the study will be released for further implementation.

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LIST OF PUBLICATIONS

JOURNALS:

1. **Sandipta Das** and D. P. Angadi (2020). **Land use-land cover (LULC) transformation and its relation with land surface temperature changes: A case study of Barrackpore Subdivision, West Bengal, India.** Remote Sensing Applications: Society and Environment (Elsevier), Volume 19. https://doi.org/10.1016/j.rsase.2020.100322.
2. **Sandipta Das** and D. P. Angadi (2021). **Assessment of urban sprawl using landscape metrics and Shannon's entropy model approach in town level of Barrackpore sub-divisional region, India.** Modeling Earth Systems and Environment (Springer). https://doi.org/10.1007/s40808-20-00990-9.
3. **Sandipta Das** and D. P. Angadi (2021). **Land use land cover change detection and monitoring of urban growth using remote sensing and GIS techniques: a micro-level study**. GeoJournal (Springer). https://doi.org/10.1007/s10708-020-10359-1.
4. **Sandipta Das** and D. P. Angadi (2020). **Spatio-temporal analysis of urban functional development and its zone of Influence: A micro-level study of Barrackpore**

Subdivision, West Bengal. Urban India Vol 40 (II) July-December 2020. Publisher- National Institute of Urban Affairs.

5. **Sandipta Das** and D. P. Angadi (2021). **Assessment and characterization of dust particles from tree leaves as an indicator of air pollution in urban local bodies: A case study on Barrackpore Sub-division, West Bengal.** Indian Journal of Environmental Protection (Scopus Indexed Journal), Vol 41 (5), pp-483-494. ISSN – 0253-7141.

Paper in communication Stage

1) Communicate the research Papers in Sustainable Water Resources Management (Springer Publication) on 24th May, 2021. Paper Entitle "**Appraisal of groundwater quality variation in rural-urban areas using Geographic Information System approach- A case study of Barrackpore sub-division, West Bengal".**

Paper presented in Conference/ Seminar attended

1. **Impact of growing urban population on environment-A special emphasis in North 24 Parganas district, West Bengal, using geospatial approaches.** International Seminar on Climate Change, Environment and Society, March 29-30, 2017, Department of Geography, Sree Sankaracharya University of Sanskrit, Kalady, Kerala.
2. **Site suitability analysis for municipal solid waste disposal in Mangalore City Corporation, Karnataka- using geospatial technology**. Union Geographic Information Technologists (UGIT) 6th International Conference, November 9-11, 2017, Department of Geography, Bangalore University, Bangalore, India.
3. **Change detection of urban growth dynamics in Barrackpore Subdivision Area, West Bengal 1972-2016 from Landsat observation**. XIII DGSI International Geography Conference on Sustainable Rural Development- Geospatial Solutions, September 20-22, 2018 Department of Geography & Geoinformatics, Bangalore University, Bangalore.
4. **Trend of urban growth and its impact on the micro-climate of Barrackpore Subdivision, West Bengal.** 7th (UGIT) International Conference on "Climate Change, Disaster Risk Reduction And Sustainable Development Through Geospatial Technologies", November 24-25, 2018, Department of Geography, University Of Peradeniya, Srilanka.

5. **Characterization of dust particles from tree leaves as an indicator of air pollution in ULB (Urban Local Bodies): A case study on Barrackpore Subdivision**. XIII International Geographical Union (IGU)-INDIA of International conference on "Heading towards Zero: Sustainable Development in Economy, Environment, and Society", October 19-21, 2019, Central University of Haryana.
6. **Nature of urban growth and its effect on land surface temperature increases from Landsat observation – A micro-level case study"**. 41th National Association of Geographers, India congress, December 28-30, 2019, Sagar Agricultural University.
7. **Spatio-temporal analysis of urban functional development and its zone of influence: A micro-level study**. IGS- International E-Conference on "Earth Sciences and Sustainable Development Goals", August 5-7, 2021, Osmania University, Hyderabad, Telangana in Collaboration with the Indian Geographical Society.

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